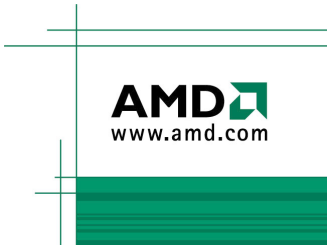
On-Die Thermal Diode Characterization Application Note

25443 rev 1.01 – September, 2001



Use of AMD Thermal Diode

- Typical thermal diode I-V and Voltage-Temperature curves provided on following slides
- AMD recommends using dual sourcing currents to measure temperature
- Single sourcing current
  - Measures absolute voltage
  - Can vary between die and process revisions
  - Requires use of lookup table to compute temperature
- Dual sourcing currents
  - Measures voltage differential between two sourcing currents
  - Much less susceptible to die and process revisions
  - Allows direct computation of temperature using a differenced diode equation provided below

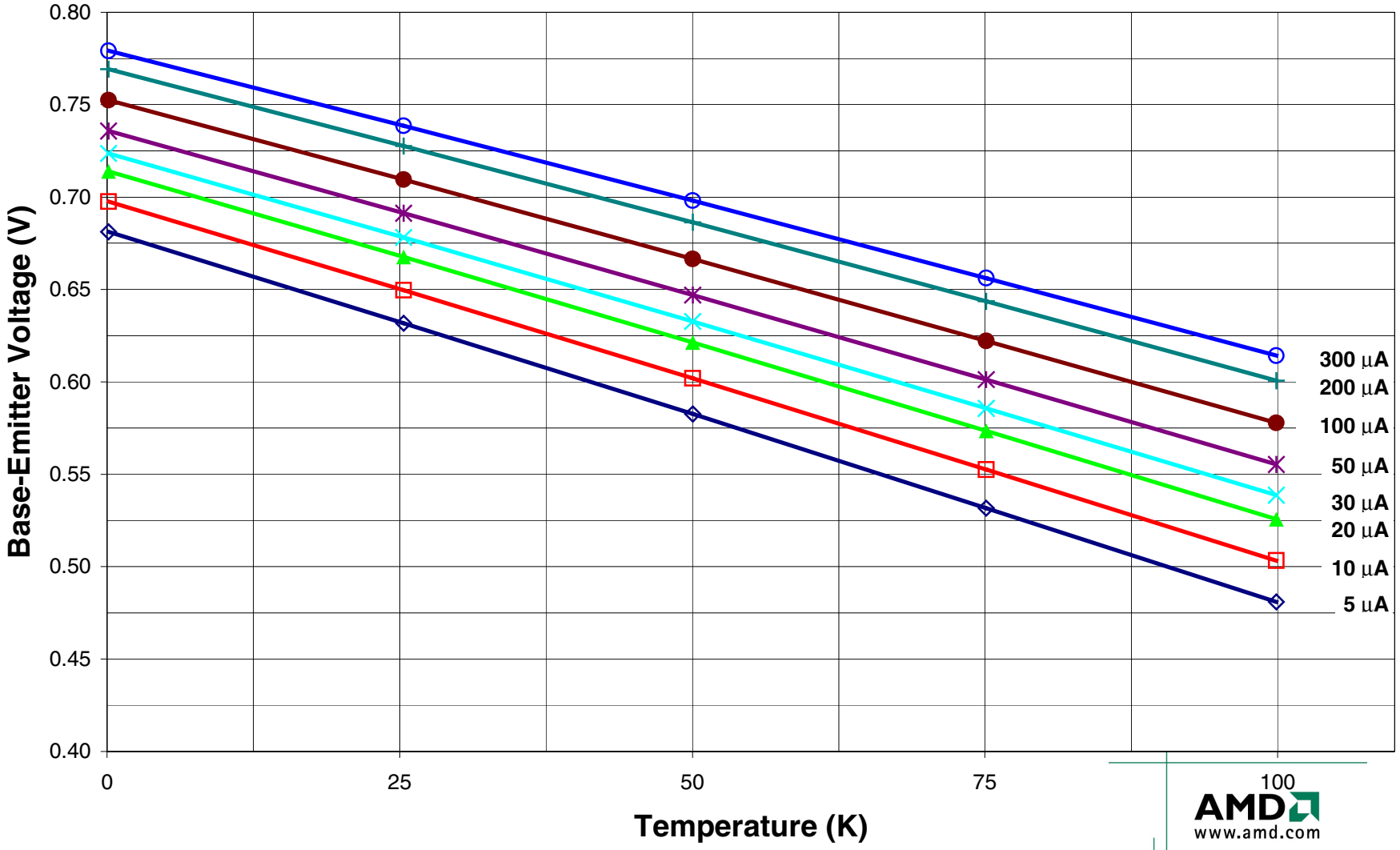
$$T = \frac{\Delta V_{BE}}{n \cdot \ln(N) \cdot k / q}$$

n: ideality factor
k,q: physical constants
V_{BE}: base emitter voltage

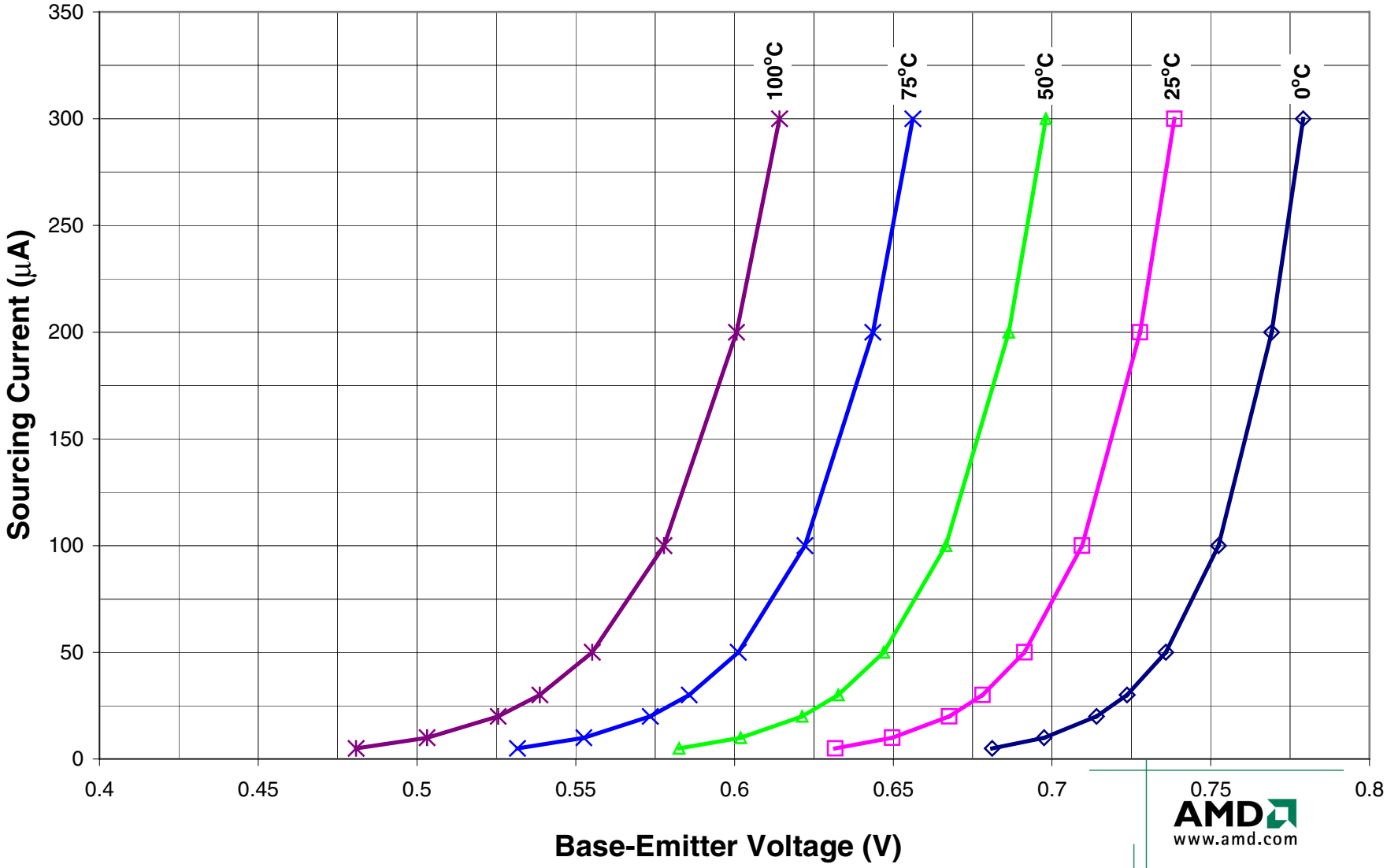
T: diode temperature
N: ratio of collector currents (equals ratio of sourcing currents)

  - Depends upon variation in ideality factors
  - Confidence level for thermal diode provided in slide after diode curves

"Typical" Voltage vs. Temperature Curves for AMD Athlon™ Processor Thermal Diode



"Typical" I-V Curves for AMD Athlon™ Processor Thermal Diode



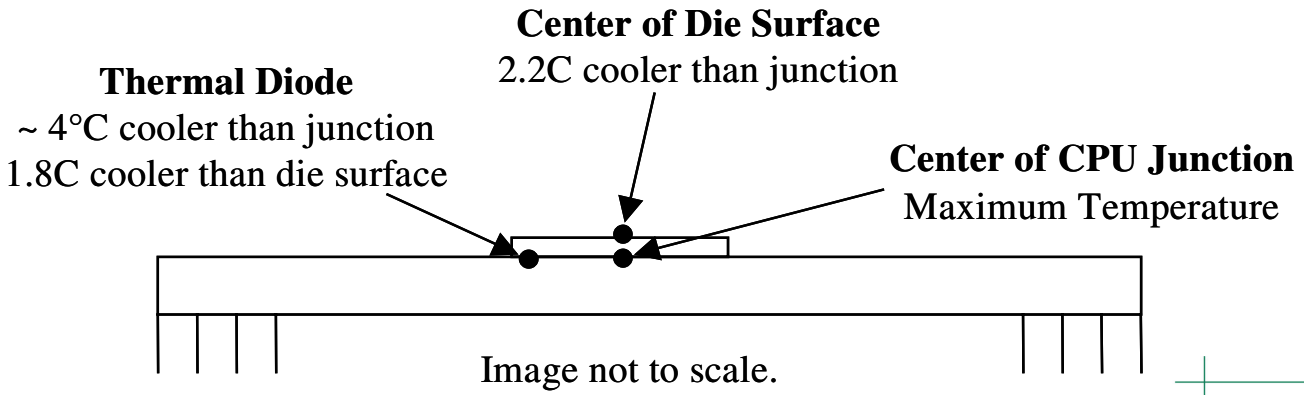
AMD Thermal Diode Confidence Level

- The following data taken on 46 samples using a highly accurate temperature-controlled oil bath and current and voltage meter.
- This data covers multiple die and process revisions.

# CPUs	46
Mean =	1.008689
Stdev =	0.000645
Max =	1.010573
Min =	1.007904
Upper Spec Limit =	1.016
Lower Spec Limit =	1.002
$C_{p,k}$ =	**3.46**

Spatial Offset

- See the below sketch to aid in understanding the following discussion.
- Based on simulations and experimental data, the following temperature relationships apply:
  - center of the die surface (backside of silicon) is 2.2°C cooler than the center of the junction (active silicon).
  - thermal diode is 4°C cooler than the center of the junction in a worst-case usage scenario.
- Based on this, a CPU thermal solution designed using the die surface temperature should have 1.8°C additional margin when using the thermal diode.
  - The customer does not need to account for a spatial offset, since this offset is built into the specification.
- **AMD's 95°C mobile die temperature specification is valid when reading from the temperature diode.**



~ 1.8°C additional thermal margin when using thermal diode instead of die surface temperature.

Die Temperature Measurement

- AMD does not recommend making direct die surface temperature measurements.
  - These measurements are intrusive and prone to error due to the temperature gradient between the die surface and the heat sink caused by the thermal interface material.
- For the AMD recommended methodology for measuring die temperature, see "Methodology for Measuring Temperature on Ceramic Pin Grid Array Packaged

  AMD Athlon™ and AMD Duron™ Processors with and without an On-Die Temperature Diode" (Document PID# 24228).
  - Techniques are provided for processors without an on-die diode, such as the Spitfire based AMD Duron™ processor, and processors with an on-die diode, such as the Morgan based AMD Duron™ or Palomino-based AMD Athlon™ processors.
- For Spitfire in a mobile setting, the recommended technique for die temperature uses a thermocouple to measure the temperature on the back of the ceramic and another thermocouple on the heat sink base 2 mm directly above the die.
  - This correlation was experimentally derived using thermal test vehicles to provide the junction/core temperature rather than the temperature on the surface of the die.

Measurement Offset

- Separate from the spatial offset, a measurement offset may need to be used depending on which temperature sensor is used.
- The measurement offset is caused by differences between the temperature sensor designs used by various manufacturers.
- Offset correctable in BIOS; programmable offset feature available in some temperature sensors
- Contact the temperature sensor manufacturer to determine what measurement offset is needed, if any, for a given temperature sensor model.
- AMD recommends that a temperature sensor that uses dual sourcing currents along a differential pair be used for best accuracy.
- AMD has worked with both Analog Devices and Maxim to ensure that the AMD thermal diode works properly with their temperature sensors. AMD is looking at temperature sensors from other manufacturers.